Estimating the Burden of Disease from Water, Sanitation, and Hygiene at a Global Level

Annette Prüss,[1] David Kay,[2] Lorna Fewtrell,[2] and Jamie Bartram[1]

[1]World Health Organization, Protection of the Human Environment, Geneva, Switzerland; [2]Centre for Research into Environment and Health, University of Wales, Aberystwyth, Ceredigion, Wales, United Kingdom

We estimated the disease burden from water, sanitation, and hygiene at the global level taking into account various disease outcomes, principally diarrheal diseases. The disability-adjusted life year (DALY) combines the burden from death and disability in a single index and permits the comparison of the burden from water, sanitation, and hygiene with the burden from other risk factors or diseases. We divided the world's population into typical exposure scenarios for 14 geographical regions. We then matched these scenarios with relative risk information obtained mainly from intervention studies. We estimated the disease burden from water, sanitation, and hygiene to be 4.0% of all deaths and 5.7% of the total disease burden (in DALYs) occurring worldwide, taking into account diarrheal diseases, schistosomiasis, trachoma, ascariasis, trichuriasis, and hookworm disease. Because we based these estimates mainly on intervention studies, this burden is largely preventable. Other water- and sanitation-related diseases remain to be evaluated. This preliminary estimation of the global disease burden caused by water, sanitation, and hygiene provides a basic model that could be further refined for national or regional assessments. This significant and avoidable burden suggests that it should be a priority for public health policy. *Key words*: burden of disease, diarrhea, environmental exposure, hygiene, sanitation, water, water supply. *Environ Health Perspect* 110:537–542 (2002). [Online 4 April 2002]
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The Global Burden of Disease study (GBD) estimated the burden of 107 major diseases and 10 risk factors at global and regional levels, using an internally consistent approach (*1*). Estimates were reported in summary measures of population health combining mortality and morbidity, in terms of the disability-adjusted life year (DALY). This initial approach has prompted a series of replications at the individual country level. Such assessments provide an important input to the rational development and evaluation of policies by the health sector and activities of other sectors that directly manage or influence the determinants of health. Additional information required for the rational development of such policies and activities includes the effectiveness and cost-effectiveness of interventions, social considerations, the availability of resources, and the type of policy environment.

Information on disease burden relating to risk factors—rather than diseases—is likely more relevant to policy because it may allow action to be directly targeted to modify exposure. As a result of increasing interest in such risk factors, the World Health Organization is currently involved in assessing the disease burden of about 20 risk factors in an internally consistent way. Six of these risk factors focus on environmental and occupational health concerns, one of which is water, sanitation, and hygiene. Methods for their assessment are currently being developed (*2–4*).

An original estimate for 1990 examined water, sanitation, and hygiene in terms of diarrheal and selected parasitic diseases, based on the partial attribution of their disease burden to the risk factor (*1*). It was found that the worldwide risk factor accounted for 5.3% of all deaths and 6.8% of all DALYs. Other communicable (e.g., typhoid, hepatitis A, schistosomiasis) and noncommunicable (arsenicosis, fluorosis, methemoglobinemia) diseases were not considered in this first assessment.

The risk factor "water, sanitation, and hygiene," as investigated here, comprises a number of interrelated transmission pathways, composed of competing or complementing events for causing disease. The number of resulting diseases is large. Fecal–oral diseases account for an important part of this disease burden and are the main focus of this article. Their transmission routes, illustrated in Figure 1, are complex. Human and animal excreta can affect human health through drinking water, sewage, indirect contact, and food through various pathways. This first exposure-based assessment of disease at the global level should therefore be considered an initial estimate, which will undergo refinement as additional information becomes available.

Methods

In this assessment, we defined the risk factor "water, sanitation, and hygiene" to include the following transmission pathways, although not all of them are accommodated in the assessment presented below:

- Transmission through ingestion of water—such as during drinking and, to some extent, bathing. This category includes diseases from fecal–oral pathogens, arsenicosis, fluorosis, and diseases from other toxic chemicals.
- Transmission caused by lack of water linked to inadequate personal hygiene. This would include diseases such as trachoma and scabies.
- Transmission caused by poor personal, domestic, or agricultural hygiene. This includes person-to-person transmission of fecal–oral pathogens, food-borne transmission of fecal–oral pathogens as a result of poor hygiene, or use of contaminated water for irrigation or cleaning.
- Transmission through contact with water (through bathing or wading) containing organisms such as *Schistosoma*.
- To a certain extent, transmission through vectors proliferating in water reservoirs or other stagnant water or certain agricultural practices (e.g., malaria, lymphatic filariasis) should also be included (how or whether this can be quantified is currently unclear).
- Transmission through contaminated aerosols from poorly managed water systems (e.g., legionellosis).

Although they are water-related, we did not consider injuries that could be prevented by appropriate water management in the present estimate.

Table 1 lists diseases relating to water, sanitation, and hygiene and their inclusion in the present estimate, but Table 1 is not exhaustive. The links between water and health are more extensive and complex than the more direct causes of health investigated in

Address correspondence to A. Prüss, World Health Organization, Protection of the Human Environment (PHE), 20 Avenue Appia, CH-1211 Geneva 27, Switzerland. Telephone: + 41-22-791-3584. Fax: + 41-22-791-4159. E-mail: pruessa@who.int

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works such as the GBD study and as reported here. The role of inadequate water for food production, and therefore nutrition, will likely be particularly important. Malnutrition caused an estimated 11.7% of all deaths and 15.9% of DALYs in 1990 (*1*).

We estimated the disease burden for 14 regions corresponding to those of the *World Health Report 2000* (*5*). In this grouping, countries are classified according to continent and level of child and adult mortality.

Infectious diarrhea. Infectious diarrhea is probably the largest contributor to the disease burden from water, sanitation, and hygiene. It cannot entirely be attributed to water, sanitation, and hygiene because it is also transmitted through food at an industrial scale (other than irrigation by sewage) and through the air. We therefore chose an estimation of disease burden based on exposure information, rather than attribution of disease burden.

Exposure. Although actual exposure occurs at the household or individual level, information on both exposure and risk is generally only available at the community or regional level. We therefore adopted a "scenario-based" approach for this estimate of disease burden. In this approach, we ascribed the population to typical exposure or situation scenarios (e.g., representative combinations of risk factors at commonly encountered levels, which can be extended to include policy situations). We then compiled risk information from the literature to match each of these typical scenarios.

Regarding water, sanitation, and hygiene, we used six exposure scenarios, defined in Table 2. Different fecal–oral pathogen loads in the environment are associated with different scenarios, influencing the risks of contracting fecal–oral infections. To reflect this, four of the scenarios were associated with high and two with low or medium fecal–oral pathogen load in the environment. A low to medium load is characterized by more than 98% coverage in improved water supply and sanitation and/or a regional annual incidence of diarrhea of < 0.3/person/year.

We selected the exposure categories according to available information on exposure–risk relationships and information from the *Global Water Supply and Sanitation Assessment 2000* (*6*). Table 3 shows the distribution of the population according to these scenarios.

Figure 2 shows the links between the different scenarios. Scenarios I and III do not occur on a large scale and, in global terms, are probably negligible; hence their omission from Table 3. They are nevertheless important in policy terms and therefore retained in the model described in Figure 2.

Relative risks. The ideal situation (scenario I) has been ascribed a relative risk (RR) value of 1.0. To illustrate the major differences between scenarios II and I, in scenario II the pathogen load is mostly transferred from land to water, with insufficiently treated sewage being discharged to surface waters or potentially contaminating drinking water. In scenario I, the "ideal" scenario, this would not occur.

We calculated RRs between scenarios from the literature. For the risk transition between scenarios I and II (ideal situation to regulated water supply), we used the review prepared by Mead et al. (*7*). It reports that about 35% of intestinal illness in the United States are food borne. After deducting the portion of food-borne transmission, and accounting for likely ratios of person-to-person transmission through aerosols of certain viruses (estimated as up to 25% for rotavirus and astrovirus), the remaining fraction attributable to water, sanitation, and hygiene is about 60%. This order of magnitude is supported by intervention studies acting on point-of-use treatment of drinking water in Canada (*8,9*) and hand washing in the United States (*10*), reporting reductions of 40%, 35%, and 48%, respectively. A 60% reduction in disease corresponds to an RR of 2.5 [RR = 1/(1 – reduction)] for scenario II when compared with scenario I (i.e., the "ideal").

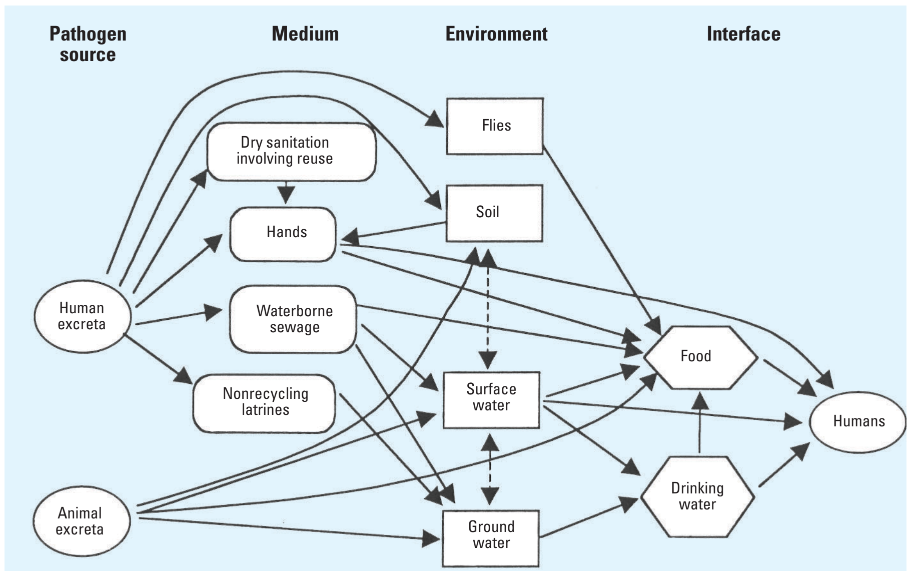

Figure 1. Transmission pathways of fecal–oral disease.

Table 1. Diseases related to water, sanitation, and hygiene.

Disease outcome	Inclusion in current estimate
Infectious diarrhea[a]	Yes
Typhoid and paratyphoid fevers	Included in infectious diarrhea for this analysis
Acute hepatitis A	Future inclusion
Acute hepatitis E and F[b]	Data may not be available in near future
Fluorosis	Future inclusion
Arsenosis	Future inclusion
Legionellosis	Future inclusion
Methamoglobinamia	Future inclusion
Schistosomiasis[a,b]	Yes
Trachoma[a,b]	Yes
Ascariasis[a,b]	Yes
Trichuriasis[a,b]	Yes
Hookworm[a,b]	Yes
Dracunculiasis[b]	Disease close to eradication
Scabies	Current knowledge insufficient to attribute fraction to this risk factor
Dengue[a]	Current knowledge insufficient to attribute fraction to this risk factor
Filariasis[a]	Current knowledge insufficient to attribute fraction to this risk factor
Malaria[a]	Current knowledge insufficient to attribute fraction to this risk factor
Japanese encephalitis[a]	Current knowledge insufficient to attribute fraction to this risk factor
Leishmaniasis[a]	Current knowledge insufficient to attribute fraction to this risk factor
Onchocerciasis[a]	Current knowledge insufficient to attribute fraction to this risk factor
Yellow fever	Current knowledge insufficient to attribute fraction to this risk factor
Impetigo	Current knowledge insufficient to attribute fraction to this risk factor
Drowning[a]	Current knowledge insufficient to attribute fraction to this risk factor

[a]Including cholera, salmonellosis, shigellosis, amoebiasis, and other protozoal and viral intestinal diseases; total disease burden estimated in the *World Health Report 2000* (*5*). [b]Considered to be 100% due to water, sanitation, and hygiene.

The multicountry study conducted by Esrey (*11*) provides data to allow calculation of RRs between scenarios IV, Va, Vb, and VI. According to this study, a reduction of 20.8% in diarrheal disease rates (RR = 1.26) can be observed when progressing from scenario VI to scenario Vb (i.e., when providing an improved water supply), and 37.5% (RR = 1.6) when progressing from scenario VI to scenario Va (i.e., when providing basic sanitation facilities). When progressing from scenario VI to scenario IV (i.e., when providing both an improved water supply and basic sanitation facilities), a reduction of 37.5% is also achieved. This implies that no further reduction in diarrheal disease is achieved by improving water supply when basic sanitation is already available. These data are supported by the results of Esrey et al.'s (*12*) 1991 review.

After we quantified most of the transitions between the scenarios represented in Figure 2, the shift between scenarios II and IV remains the most "data-scarce" risk transition. It represents the transition between high and low pathogen loads in the environment, or more generally between developed and developing regions with incomplete coverage of improved water supply or basic sanitation.

Intervention studies are not available because transforming environments high in pathogen load into environments low in pathogen load would imply completing the coverage in improved water supply and sanitation in a reasonable time frame and without simultaneous change in other major determinants of health, which is not possible. Some studies do, however, describe part of this risk transition between scenarios II and IV by acting on selected characteristics of the differences of these scenarios.

These differences include

- Additional improvement of drinking-water quality (scenario IV to IIIa). Introduction of point-of-use disinfection has been studied by Quick et al. (*13,14*); reductions of 44.7% in the total population and 54.5% in children have been achieved (RR = 1.80 and 2.20). Semenza et al. (*15*) found a 62% reduction in diarrhea rates for an intervention with home chlorination of drinking water, compared with those living in areas with access to piped water (RR = 2.86), whereas for individuals without a piped supply, the same intervention achieved a 85% reduction in disease (RR = 6.7).
- Improvement of basic hygiene (scenario IV to IIIb). Reductions in diarrhea morbidity have been reviewed by Huttly et al. (*16*); hand washing resulting in a median 35% reduction in diarrhea incidence (RR = 1.54).

No studies currently available adequately describe the benefits of continuous piped water supply. We consider scenario IIIb to complement scenarios IIIa and IIIc, because scenario IIIb acts on personal hygiene alone, whereas scenarios IIIa and IIIc act on improving drinking water quality.

For estimating the disease burden, we used two approaches, which differed in the assumptions relating to risk transition between scenarios II and IV. The most conservative or "minimal" estimate would only account for the improvement achieved by personal hygiene—that is, to simulate, partially, the transition to a low-pathogen environment. For a more realistic estimate, the point-of-use improvement of drinking water has also been considered. Thus, the minimal estimate supposes that the difference in risks between a low- and a high-pathogen environment equates to what can be achieved with hygiene alone, whereas the realistic estimate considers improvements in hygiene and in water supply quality. As suggested by the name, we consider the realistic estimate to be closer to reality.

We obtained the resulting RR values by multiplying the RRs between each scenario, summarized in Table 4. The starting point is an RR of 2.5 for the transition between scenario I and II. For the "minimal" estimate, the transition between scenarios II and IV is represented by the benefits that can be reached by personal hygiene (35% reduction in diarrhea incidence; see Huttly et al. (*16*)]; this is described by an RR of 1.54. Because

Table 2. Selected exposure scenarios.

Scenario	Description	Environmental fecal–oral pathogen load
VI	No improved water supply and no basic sanitation in a country that is not extensively covered by those services, and where water supply is not routinely controlled	Very high
Vb	Improved water supply and no basic sanitation in a country that is not extensively covered by those services, and where water supply is not routinely controlled	Very high
Va	Basic sanitation but no improved water supply in a country that is not extensively covered by those services, and where water supply is not routinely controlled	High
IV	Improved water supply and basic sanitation in a country that is not extensively covered by those services, and where water supply is not routinely controlled	High
IIIc	IV and improved access to drinking water (generally piped to household)	High
IIIb	IV and improved personal hygiene	High
IIIa	IV and drinking water disinfected at point of use	High
II	Regulated water supply and full sanitation coverage, with partial treatment for sewage, corresponding to a situation typically occurring in developed countries	Medium to low
I	Ideal situation, corresponding to the absence of transmission of diarrheal disease through water, sanitation, and hygiene	Low

Table 3. Distribution (%) of the population in scenarios, 2000.

Region (mortality in children and adults)	Scenario				
	II	IV	Va	Vb	VI
African					
Child: high; adult: high	0	54	5	6	35
Child: high; adult: very high	0	42	0	9	38
American					
Child: very low; adult: very low	99.8	0	0	0	0.2
Child: low; adult: low	0	76	1	9	14
Child: high; adult: high	0	68	0	7	25
Eastern Mediterranean					
Child: low; adult: low	0	83	5	8	4
Child: high; adult: high	0	66	0	16	18
European					
Child: very low; adult: very low	100	0	0	0	0
Child: low; adult: low[a]	0	79	8	1	12
Child: low; adult: high[a]	0	94	5	0	1
Southeast Asian					
Child: low; adult: low	0	70	3	7	19
Child: high; adult: high	0	35	0	53	12
Western Pacific					
Child: very low; adult: very low	100	0	0	0	0
Child: low; adult: low	0	42	1	33	4

Adapted from *Global Water Supply and Sanitation Assessment 2000* (*6*), assuming that improved water supplies are most likely to have sanitation coverage.
[a]Data required for analysis partly missing.

the "unexposed" group in risk transition from scenario I to scenario II (described by the RR of 2.5) becomes the "exposed" group in the transition from scenario II to scenario IV (characterized by the RR = 1.54), we can multiply the two RRs and thereby obtain the RR for the transition from scenario I to scenario IV (2.5 × 1.54) of 3.85. Similarly, for the realistic estimate, the transition from scenario II to scenario IV is described by an improvement in hygiene (RR = 1.54) and also by an improvement in water quality [characterized by Quick et al. (*13*), RR = 1.80]. Thus, for the realistic estimate, the RR at scenario IV (compared with scenario I) results from the multiplication of these three RRs (i.e., 2.50 × 1.54 × 1.80 = 6.9). The same applies for estimating the RRs for scenarios V and VI.

Estimation of uncertainty. Because the RR values originate mainly from surveys or reviews that do not report confidence intervals, evaluating uncertainty intervals around the point estimates is difficult. Mead et al.'s (*7*) review does not estimate any uncertainty intervals but relies on very large data samples; Esrey's (*11*) multicountry study provides confidence intervals for the transition between the scenarios. We report the RR for diarrheal disease rates as 1.26 (1.00–1.71) for the transition between scenario Vb and scenario VI (i.e., for improved water supply) and 1.6 (1.26–2.18) for the transition between scenario IV or Va to scenario VI (i.e., for basic sanitation or basic sanitation and improved water supply). We derived the RRs for diarrhea linked to hygiene practices from Huttly et al.'s (*16*) review, which estimates a median risk reduction from the considered studies, without estimating confidence intervals. Because of these data gaps and the difficulties in combining the various sources of uncertainty, we did not estimate an error margin for the overall results. The main sources of uncertainties probably lie in the lack of a reliable estimate for the risk transition between scenarios II and IV, representing the transition between a low and high pathogen load in the environment. We therefore adopted a minimal and realistic approach, using two different values (varying by a factor of almost 2) for exactly this transition between scenarios II and IV. These two estimates evaluate the sensitivity to the shift in risks associated with this transition. In general, a sensitivity analysis seems to be a suitable approach for estimating an uncertainty interval for this type of model. With a difference in risks of a factor of almost 2 between the minimal and realistic approach of scenarios III to VI, the uncertainty interval becomes about 50% around a point estimate, which seems to be plausible.

Other diseases related to water, sanitation, and hygiene. The *World Health Report 2000* (*5*) provides figures on the disease burden of additional diseases that are exclusively (or almost exclusively) caused by water, sanitation, and hygiene (Table 5). We added these figures to the figures for diarrheal disease to calculate the overall burden of illness.

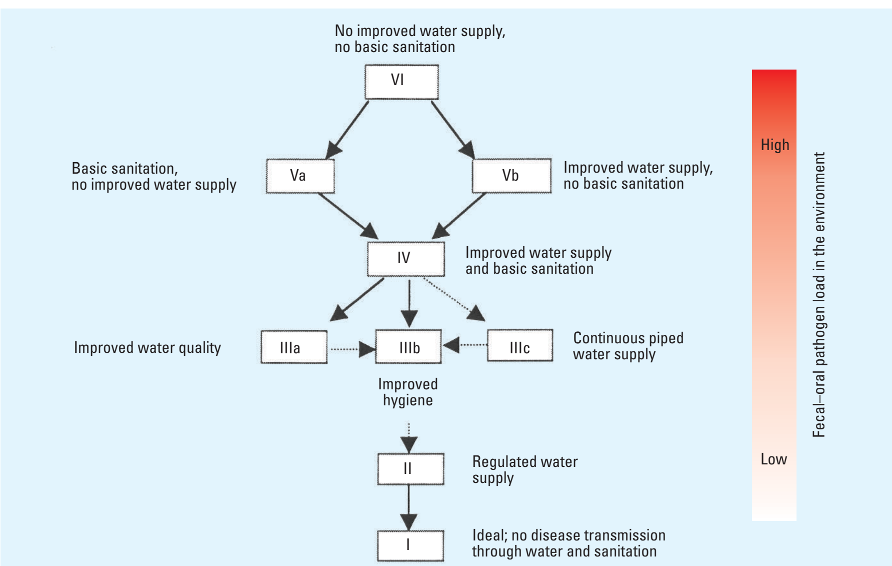

Figure 2. Scenarios determining transmission of fecal–oral pathogens.

Table 4. RRs associated with scenarios.

	Scenario						
Approach	I	II	III	IV	Va	Vb	VI
Minimal	1	2.5	2.5	3.8	3.8	4.9	6.1
Realistic	1	2.5	4.5	6.9	6.9	8.7	11.0

As already mentioned, diarrhea and those diseases listed in Table 5 do not include all the diseases contributing to the disease burden due to water, sanitation, and hygiene, but the burden from other diseases cannot currently be quantified.

To calculate mortality and disease burden, we combined the exposure distribution in the population with the RR for each scenario. For estimating region-specific incidence rates per age and sex group, we multiplied the fraction of the population (f) attributed to each scenario by its excess RR (RR – 1) (*17*) and multiplied their sum by the baseline diarrhea incidence rate (IR). This results in an overall incidence rate for each age group within each region:

$$IR_{\text{age group, region}} = IR_{\text{baseline}} \times [f_{\text{scenario I}} \times (RR_{\text{scenario I}} - 1) + f_{\text{scenario II}} \times (RR_{\text{scenario II}} - 1) + \ldots + f_{\text{scenario VI}} \times (RR_{\text{scenario VI}} - 1)]$$

This baseline incidence rate corresponds to the rate that would have been observed in an ideal scenario (scenario I), that is, the observed rate in countries falling under scenario II, divided by the RR between scenarios I and II (2.5).

We determined mortality by multiplying incidence by case fatality rates. We took the year 2000 projections of the case fatality rates and baseline diarrhea incidence rates from *Global Health Statistics* (*18*), and population figures from the *UN World Population Prospects* (*19*).

We calculated DALYs as described in the GBD study (*1*), by introducing the incidence rate for the age group per region into the DALY formula. With this formula, we discount health by 3% a year and perform age weighting. We chose these parameters solely to ensure comparability with other available information on disease burden. We made all calculations on a calculation spreadsheet (Excel).

Results

Table 6 summarizes the resulting number of deaths and disease burdens, according to the minimal and the realistic approach.

About 90% of this disease burden occurs in children younger than 5 years. Figure 3

Table 5. Worldwide disease burden caused by selected water-related diseases other than infectious diarrhea in 1999.

Disease	Deaths[a]	DALYs[a]
Schistosomiasis	14	1,932
Trachoma	0	1,239
Ascariasis	3	505
Trichuriasis	2	481
Hookworm disease	7	1,699
Total	26	5,856

[a]× 1,000.

graphically represents the actual rates per person of DALYs from diarrheal disease in children younger than 5 years per region, as determined from the realistic estimate. Figure 3 shows that the disease burden can be up to 240 times higher in developing regions when compared with a developed region. Disaggregating these data into smaller regions or different strata of the population (e.g., socioeconomic strata) would lead to even greater differentials.

When adding the disease burden from diarrhea estimated by the realistic approach to other diseases related to water, sanitation, and hygiene (presented in Table 5), the totals amount to 2,213,000 deaths and 82,196,000 DALYs per year. This amounts to 4.0% of all deaths and 5.7% of all DALYs if compared with the figures reported for 1999 (*5*).

Discussion

The discrepancy between the present results and earlier estimates (*1*) can be explained by the different method employed here, and a trend of decreasing overall mortality over time (*20*). In fact, we determined the case-fatality rates, a direct input parameter into the calculations, on the basis of *Global Health Statistics* (*18*); the rate decreased significantly between 1990 and the projections made for the year 2000, which we used in our calculations. The decrease in these case-fatality rates is the main driver of the decrease of disease burden over time.

The present method represents a clear improvement over the previous estimates by an approach based on combining exposure with evidence-based exposure–risk information, in a manner open to scrutiny, whereas the previous estimate of the GBD study (*1*) was based on expert judgment of attributable fractions. With the new approach presented here, it would be possible, for example, to estimate the health gains that could derive from various improvements, such as increasing access to improved water sources or increasing sanitation coverage. The new estimates reflect the region-specific exposures, as opposed to assuming a single attributable fraction for all developing regions (*1*). Additional precision of the estimates could be obtained by calculating an attributable fraction, based on the exposure data and RRs determined in this model, and applying it to a reliable burden of disease estimate for each of the considered conditions, that is, values previously obtained from national burden of disease studies.

As already shown by the preliminary estimates performed in the original GBD study (*1*), water, sanitation, and hygiene are major causes of mortality and disability. Indeed, this group is one of the most important risk factors overall. The burden created by this risk factor exceeds many major diseases (e.g., malaria or tuberculosis).

Diseases related to water, sanitation, and hygiene disproportionately affect poorer members of society. The reasons behind this are complex and interconnected. They include better access by the more wealthy to services and/or less polluted environments.

The estimate presented here represents the disease burden due to water, sanitation, and hygiene from a selected group of illnesses. As we have shown, quantification of the disease burden due to water, sanitation, and hygiene is a complex task because of *a*) the numerous interrelated causes leading to transmission of water-related diseases (source factors, pathway factors, behavioral factors); *b*) the complex exposure patterns at household and community level; and *c*) the scarce information on the risk factor–disease relationship. In terms of a "true" picture of the disease burden due to water, sanitation, and hygiene, the estimates reported here are conservative for a number of reasons:

- The exposure approach does not account for all routes, such as exposure to recreational water or sewage polluted shellfish.
- Numerous diseases are not currently quantifiable, particularly those relating to water resource management and agricultural methods involving disease vectors.
- We based the estimate predominantly on risk information from intervention studies; in water, sanitation, and hygiene, intervention studies tend to underestimate attributable risk, because an intervention needs to be implemented at community level in order to eliminate related disease burden.

The diseases listed in Table 1 (including malaria, leishmaniasis) with as yet unknown fractions due to water, sanitation, and hygiene sum up to a total of 1,609,000 deaths and 67,482,000 DALYs for 1999. A significant

Table 6. Disease burden from diarrheal disease, total deaths, and DALYs per region, 2000.

Region/mortality in children and adults	Minimal approach Deaths[a]	Minimal approach DALYs[a]	Realistic approach Deaths[a]	Realistic approach DALYs[a]
African				
Child: high; adult: high	169.2	5,905	340.7	11,888
Child: high; adult: very high	202.6	7,095	406.8	14,247
American				
Child: very low; adult: very low	0.5	64	0.5	65
Child: low; adult: low	47.9	1,752	97.6	3,573
Child: high; adult: high	10.2	380	20.7	769
Eastern Mediterranean				
Child: low; adult: low[b]	33.5	1,233	68.9	2,535
Child: high; adult: high	119.8	4,393	243.0	8,910
European				
Child: very low; adult: very low	0.8	76	0.8	76
Child: low; adult: low[b]	2.0	157	4.2	321
Child: low; adult: high[b]	1.5	124	3.0	256
Southeast Asian				
Child: low; adult: low[b]	50.1	1,801	101.9	3,660
Child: high; adult: high	406.1	12,968	817.4	26,099
Western Pacific				
Child: very low; adult: very low	0.3	28	0.3	28
Child: low; adult: low[b]	40.1	1,946	80.6	3,912
Total	1,085	37,923	2,187	76,340
Percentage of total disease burden compared with WHO data (*5*)	1.9%	2.6%	3.9%	5.3%

[a]× 1,000. [b]Data required for analysis partly missing.

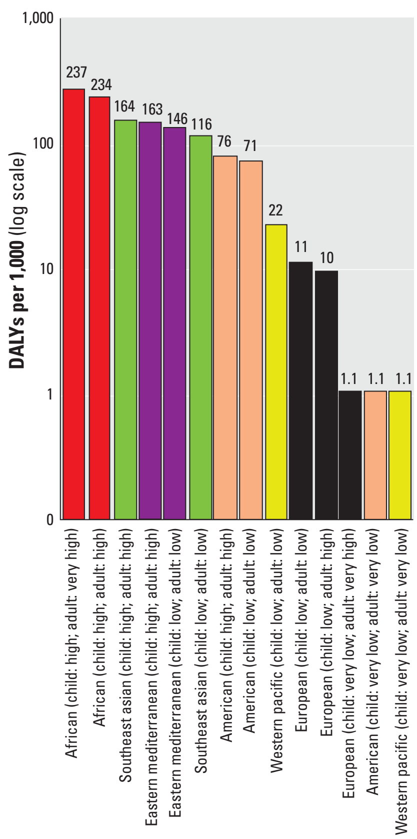

Figure 3. Diarrheal disease from water, sanitation, and hygiene: DALYs per 1,000 children (under 5 years old) by region.

fraction of this burden should likely be added to the estimate presented here. An additional factor that needs be considered is malnutrition, related to water scarcity, which alone accounts for a burden more than double that reported here.

Regarding infectious diarrhea, the present estimate (based on the "realistic" approach) is very close to the total figure reported by the *World Health Report 2000* (*5*), despite our conservative approach, in particular in terms of DALYs. The comparison of the method underlying the *World Health Report 2000* with those used in the literature points to two issues in particular. First, the diarrhea incidence rates of intervention studies in the area of water, sanitation, and hygiene are invariably of an order of magnitude higher than incidence rates specified in the *Global Health Statistics* (*18*) (which are relevant to estimates of the *World Health Report 2000*). Second, for estimating disease burden, the group "diarrhea" comprises a number of conditions of varying severity. However, we considered only a single duration of "diarrhea" with a very low disability weight (around 10% disability), although some diarrheal diseases are known to be very disabling during the acute phase of the disease. An improvement in estimates could be achieved by distinguishing diarrheal diseases by their severity.

We performed this estimate at a global level, and therefore it does not permit a more detailed selection of exposure or situation scenarios. However, if such an estimate were performed at a national level, it should be possible to refine the assessment by selecting locally specific scenarios and risk estimates if available.

The results presented here also show the high potential for disease reduction by simple interventions such as safe drinking water storage and disinfection in the home (*13*), which is illustrated by the difference of disease burden between the "minimal" and "realistic" approaches.

Although the estimates presented here represent a good baseline estimate, we need additional research to disentangle the complex web of risk factors involved in fecal–oral transmission of disease. Such information will allow policy makers to act on reducing fecal–oral diseases in an even more targeted way.

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